

# The DarkSide-G2 experiment at LNGS

for the DarkSide collaboration  
Emilija Pantic

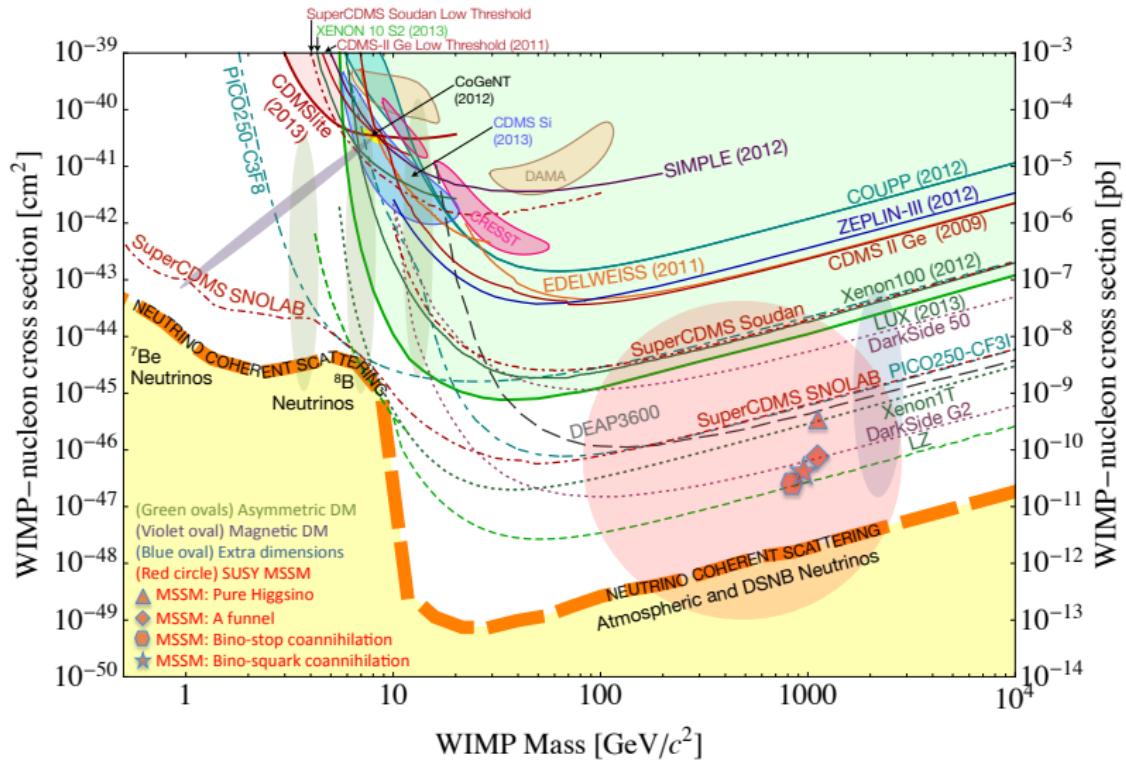
UCLA, UC Davis



By S.Walker

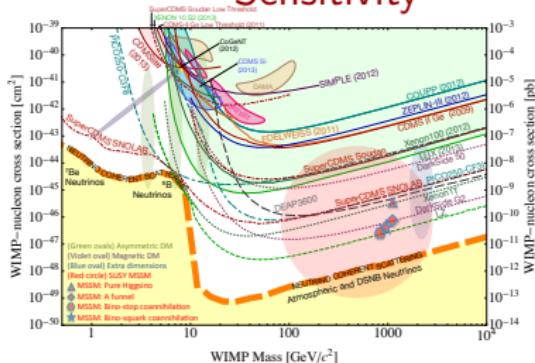
# DarkSide-G2 sensitivity in a Dark Matter race

Achieve sensitivity of  $\sigma \sim 2 \times 10^{-47} \text{ cm}^2$  in 18 ton-year.

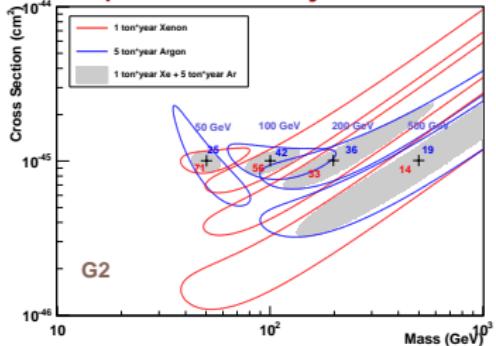


# DarkSide-G2 in a Dark Matter race

## Sensitivity



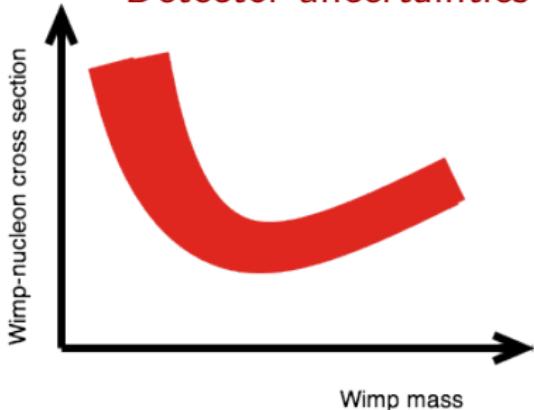
## Complementarity



## Timescale



## Detector uncertainties



# The DarkSide-G2 Collaboration



is supported by NSF, DOE, INFN and other agencies

Princeton University, USA (x2)  
University of Chicago, USA  
University of Houston, USA  
University of Massachusetts, USA  
University of Hawaii, USA  
Temple University, USA  
Augustana College, USA  
Fermilab, USA  
LLNL, USA  
LANL, USA  
BNL, USA  
PNLA, USA  
SLAC, USA  
UC Davis, USA  
BHSU, USA  
UCLA, USA  
Virginia Tech, USA

INFN LNGS, IT  
Gran Sasso Science Institute, IT  
INFN Universita degli Studi Genova, IT  
INFN Universita degli Studi Milano, IT  
INFN Universita degli Studi Napoli, IT  
INFN Universita degli Studi Perugia, IT  
INFN Universita degli Studi Roma 3, IT  
Joint Institute for Nuclear Research, RU  
SINP, Lomonosov Moscow SU, RU  
IPHC, Université de Strasbourg, CNRS/IN2P3, FR  
APC, Université Paris Diderot, FR  
Jagiellonian University, PL  
NRC Kurchatov Institute, RU  
St. Petersburg NPI, RU  
INR, UA  
IHEP, CN

# The DarkSide phased program at LNGS

Currently operating DarkSide-50 (see talk of L.Grandi)

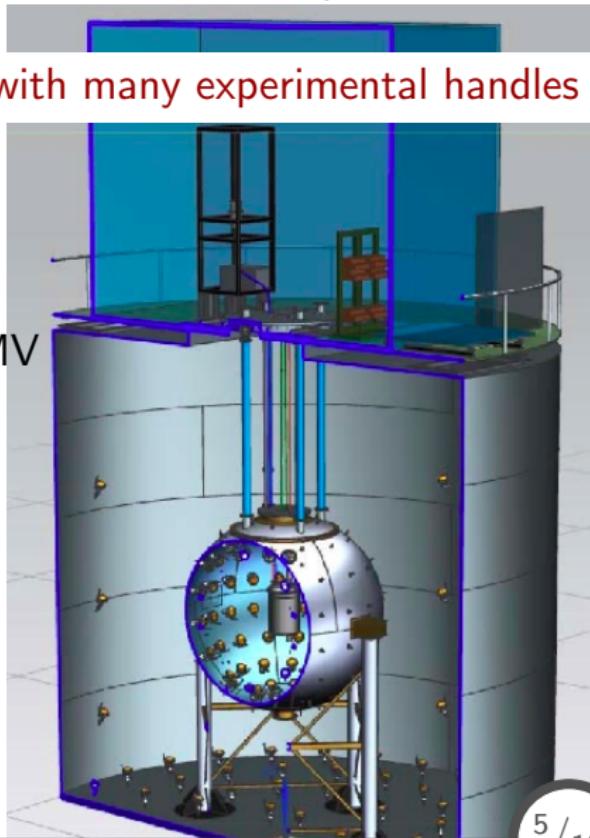
Understand&fight the background with many experimental handles

Radon-free clean room

$\mu$  and cosmogenic neutron veto - MV

Radiogenic neutron veto - LSV

Dual-phase UAr TPC



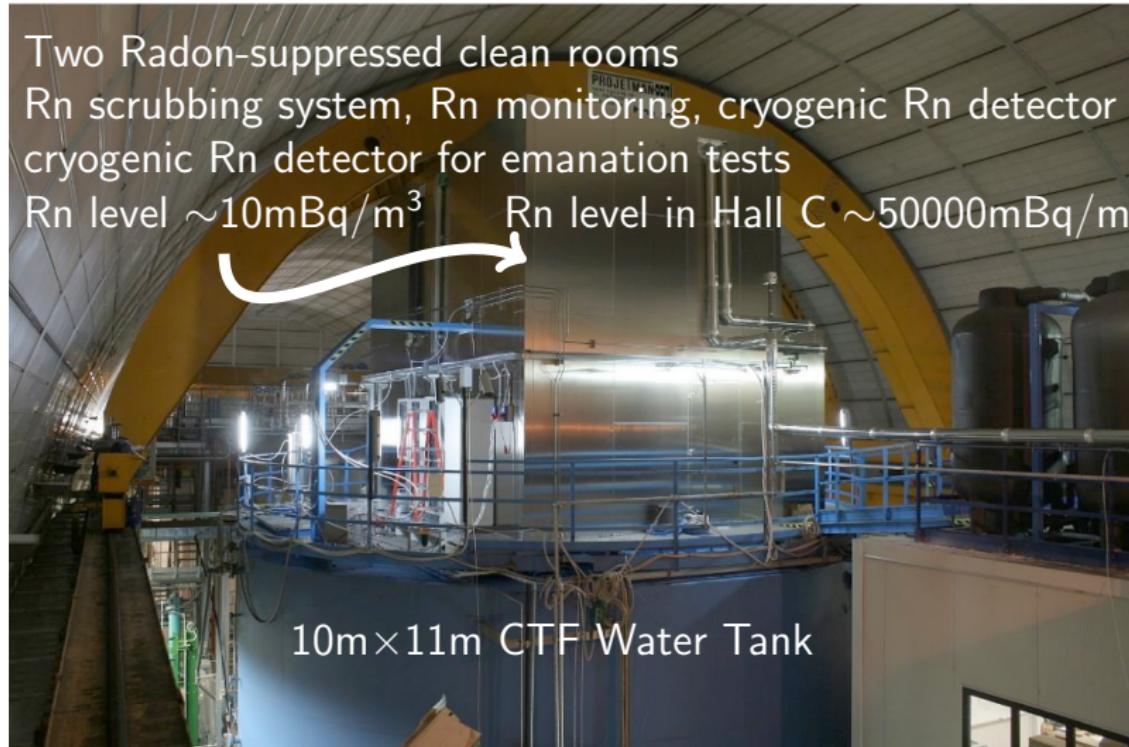
# The DarkSide-G2 at LNGS - Existing Facilities

Many facilities sized and built to house DarkSide-G2.

Two Radon-suppressed clean rooms

Rn scrubbing system, Rn monitoring, cryogenic Rn detector  
cryogenic Rn detector for emanation tests

Rn level  $\sim 10\text{mBq/m}^3$       Rn level in Hall C  $\sim 50000\text{mBq/m}^3$



# The DarkSide-G2 at LNGS - Existing facilities

Many facilities sized and built to house DarkSide-G2.

Instrumented Water Tank - Active  $\mu$  and cosmogenic n veto  
including high purity Water Plant



# The DarkSide-G2 at LNGS - Existing facilities

Many facilities sized and built to house DarkSide-G2.



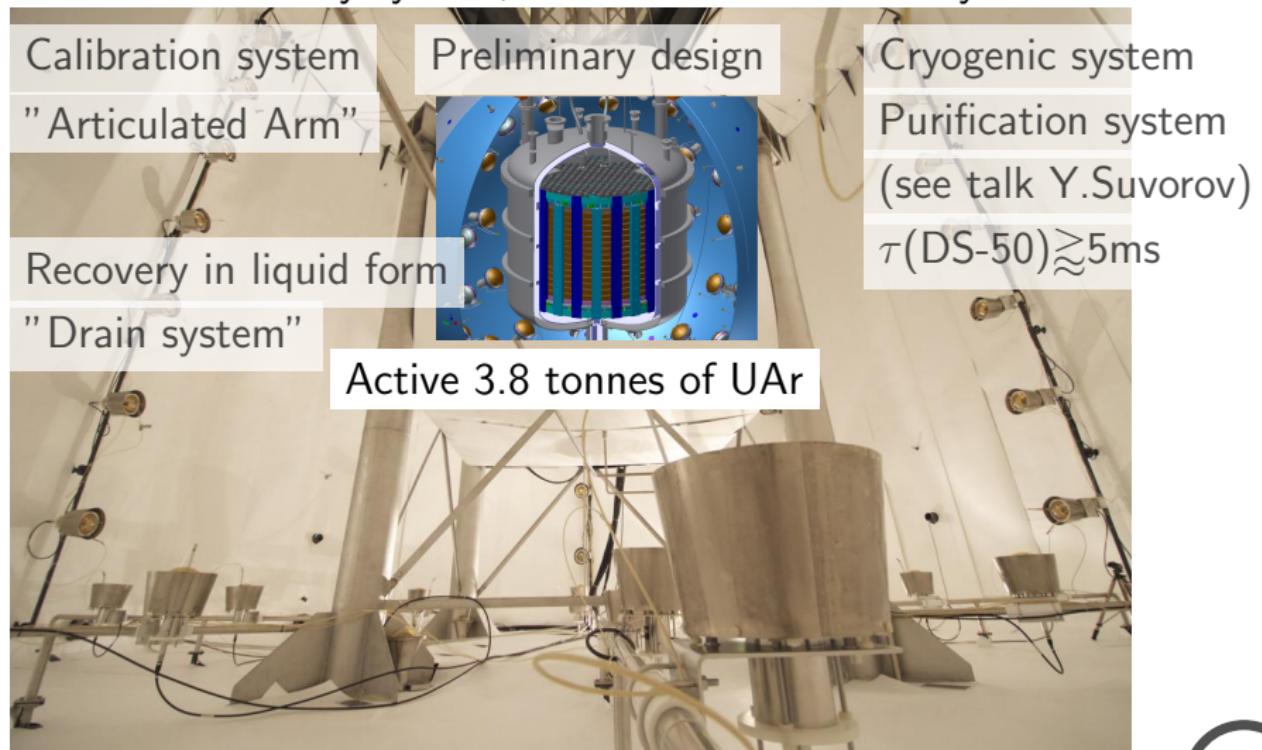
Instrumented LS Sphere - Active radiogenic n and  $\gamma$  veto  
including Boron-loaded scintillator storage, purification plants



LSV Light yield as expected  $\sim 0.5\text{PE/keV}$ .

# The DarkSide-G2 at LNGS - New facilities

Scale and improve inner detector, cryogenic/purification systems.  
Build UAr recovery system, LSV+TPC calibration system.



# The DarkSide-G2 inner detector

Feasible and scaled DarkSide-50.

Goal: high light yield and radio/chemical-purity.

Material selection ongoing

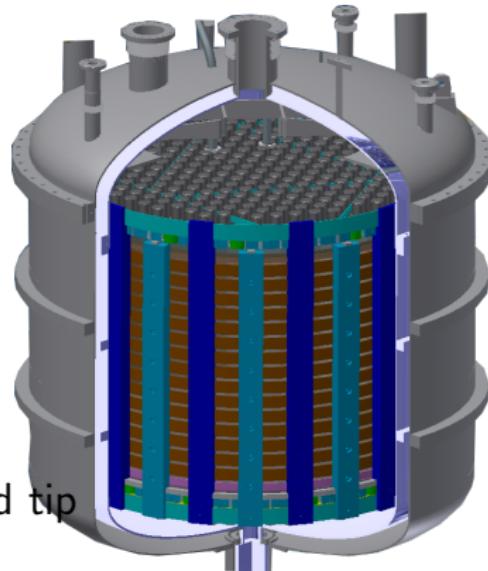
Stainless steel (cryostat, PMT support)

Copper field cage

PTFE for segmented reflective cylinder

Fused silica for windows/diving bell

Upgrade of WLS evaporator



HVFT design ready=compact with flared tip

(Tested up to 200kV)

G2 requirement with 150% contingency = 75kV



# DarkSide-G2 TPC photosensors

Baseline: 3" PMTs improved R11065 series with Cold Amplifier.

R11065-s are ultra radiopure and QE>30%  
but some are unstable at LAr temp.

Radio-pure cold amplifiers are crucial  
for stable R11065 operation in DS-50  
lower HV bias, higher dynamic range



## Intensive R&D to achieve STABLE operation

new version of 3" R11065: work with Hamamatsu,  
QE of 37% achieved, cryo-testing and material screening ongoing

---

scale to 4" PMT: work with Hamamatsu, prototype testing soon

---

develop 3"-4" hybrid photosensor: ongoing, prototype during 2014

# DarkSide-G2 Background Budget - ER

For 18 ton-year exposure in the ROI (threshold=55keV<sub>r</sub>):

Element	ER after cuts	ER after cuts&PSD	NR raw	NR after cuts
<sup>39</sup> Ar	$\mathcal{O}(4.2 \times 10^8)$	< 0.1	-	-
R11065-G2	$\mathcal{O}(2.5 \times 10^6)$	<0.01	$\mathcal{O}(280)$	0.05
cryostat&insulation	$\mathcal{O}(8.2 \times 10^6)$	<0.01	$\mathcal{O}(580)$	0.05
<sup>222</sup> Rn and daughters	$< 1.5 \times 10^5$	$\ll 0.01$	-	-
pp-Solar neutrinos	$\mathcal{O}(2.7 \times 10^5)$	$\ll 0.01$	-	-
cosmogenic neutrons	-	-	$\mathcal{O}(580)$	<0.1
Total	-	<0.1	-	<0.2

Cuts= fiducial, ROI and multi-hit cuts.

Dominant electronic recoil background is due to <sup>39</sup>Ar  $\sim \mathcal{O}(10^8)$ .

R11065-G2 prototype PTMS have radio-purity close to the requirement of DS-G2.

Identified SS batch that meets radio-purity requirements for DS-G2.

DarkSide-50 AAr data show ultra low level of <sup>222</sup>Rn (and <sup>85</sup>Kr) in UAr (analysis is ongoing).

# DarkSide-G2 Background Budget -ER

For 18 ton-year exposure in the ROI (threshold=55keV<sub>r</sub>):

Element	ER after cuts	ER after cuts&PSD	NR raw	NR after cuts
<sup>39</sup> Ar	$\mathcal{O}(4.2 \times 10^8)$	< 0.1?	-	-
R11065-G2	$\mathcal{O}(2.5 \times 10^6)$	<0.01✓	$\mathcal{O}(280)$	0.05
cryostat&insulation	$\mathcal{O}(8.2 \times 10^6)$	<0.01✓	$\mathcal{O}(580)$	0.05
<sup>222</sup> Rn and daughters	$< 1.5 \times 10^5$	$\ll 0.01$ ✓	-	-
pp-Solar neutrinos	$\mathcal{O}(2.7 \times 10^5)$	$\ll 0.01$ ✓	-	-
cosmogenic neutrons	-	-	$\mathcal{O}(580)$	<0.1
Total	-	<0.1	-	<0.2

Cuts= fiducial, ROI and multi-hit cuts.

Demonstrate <sup>39</sup>Ar rejection for DS-G2

Eq. Exposure	ER Rejection	Calibration Data
0.28ton-year ✓	PSD	DS-50 AAr (SCENE NR calibration data )
≥0.28ton-year	PSD(S2/S1, 3D)	DS-50 AAr (in-situ NR calibration data)
~18ton-year	PSD(S2/S1, 3D)	DS-50 Spike AAr with <sup>39</sup> Ar (in-situ NR cal. data)

# DarkSide-G2 Background Budget - NR

For 18 ton-year exposure in the ROI (threshold=55keV<sub>r</sub>):

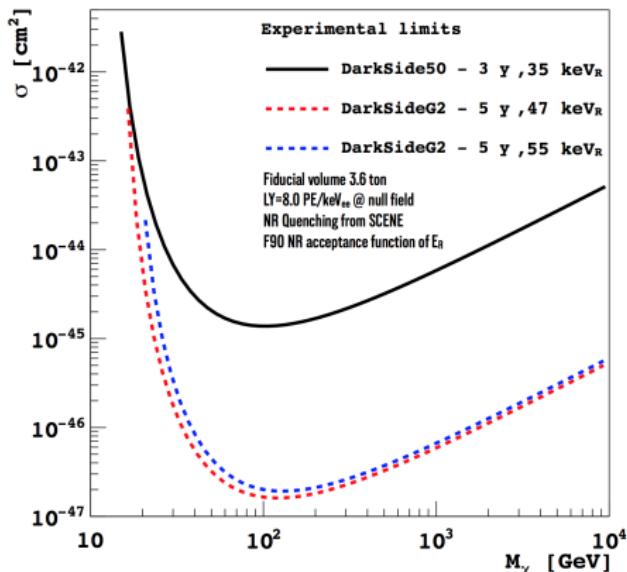
Element	ER after cuts	ER after cuts&PSD	NR raw	NR after cuts
<sup>39</sup> Ar	$\mathcal{O}(4.2 \times 10^8)$	< 0.1?	-	-
R11065-G2	$\mathcal{O}(2.5 \times 10^6)$	<0.01✓	$\mathcal{O}(280)$	0.05
cryostat&insulation	$\mathcal{O}(8.2 \times 10^6)$	<0.01✓	$\mathcal{O}(580)$	0.05
<sup>222</sup> Rn and daughters	$< 1.5 \times 10^5$	$\ll 0.01\checkmark$	-	-
pp-Solar neutrinos	$\mathcal{O}(2.7 \times 10^5)$	$\ll 0.01\checkmark$	-	-
cosmogenic neutrons	-	-	$\mathcal{O}(580)$	<0.1
Total	-	<0.1	-	<0.2

## Demonstrate NR rejection via coincidence event cuts

via MC simulation ✓: provided sufficient LSV light yield (✓) and radiopurity (in progress !)

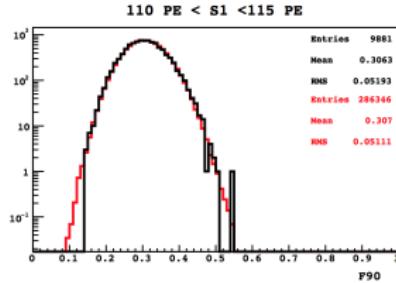
After LS is exchanged directly via calibration data

# DarkSide-G2 sensitivity



Excellent agreement between F90 model and data in ROI

LY as in DS-50  
PSD: F90 model from DS-50  
no rejection from S2/S1  
fiducialization along z axis-only  
NR model from SCENE  
zero NR bck events (MC)



# Summary

## The DarkSide-G2 timescale:

Program is following "G2 down-selection" process.

If funded, commissioning of the detector is planned for 2017.

## DarkSide-50 is a key to DarkSide-G2:

Successful integration of Borexino facilities and expertise in radio-pure liquid scintillator and water deployment. ✓

No major delays in the project's schedule. ✓

DS-50 performance and background budget are used to reliably infer G2 sensitivity and to identify and mitigate risk factors. ✓

Existing facilities for faster deployment of the G2 system. ✓

# Thank you

# DarkSide-G2 TPC signal readout

New RCE\*-based DAQ platform for inner detector.

Some of the key features are:

- Low background cold amplifiers to increase dynamic range and improve S/N ratio.
- Dual range digitizers to increase dynamic range.
- Continuous digitization with software trigger for lowest threshold.
- Select low noise equipment for detector operation, slow monitoring.
- Exploit data reduction and filtering with the RCE system (such as zero suppression, prescaling of the high energy events.)
- Integration with existing veto readout systems.

Test prototype system on DarkSide-50.

\* Reconfigurable Cluster Element, DAQ board designed at SLAC

# Underground Argon - a target for WIMP Search

Cosmic rays and radiogenic processes induce  $^{39}\text{Ar}$

Atmospheric Ar:  $^{39}\text{Ar}/^{40}\text{Ar} = 8 \times 10^{-16}$ . Rate  $\sim 1\text{Hz/kg}$

Crust Ar

$\sim$  Atmospheric Ar

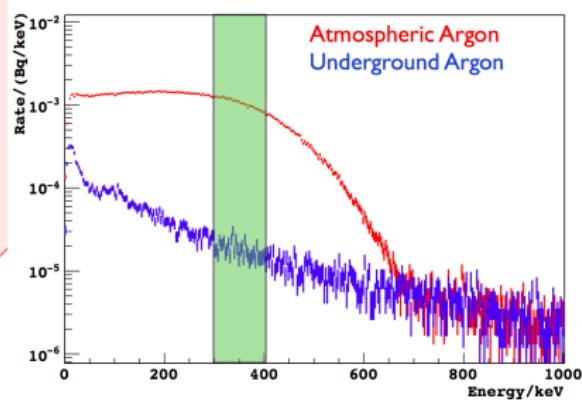
**Mantle Ar DEPLETION FACTOR >100**

$\sim 1\text{ppb U, Th}$   
 $\sim 1\text{ppm U, Th}$

arXiv:1204.6061

arXiv:1204.6024

arXiv:1204.6011



# DarkSide-G2 UAr extraction and purification

DarkSide-50: Collaboration with Kinder Morgan Doe Canyon CO<sub>2</sub> facility

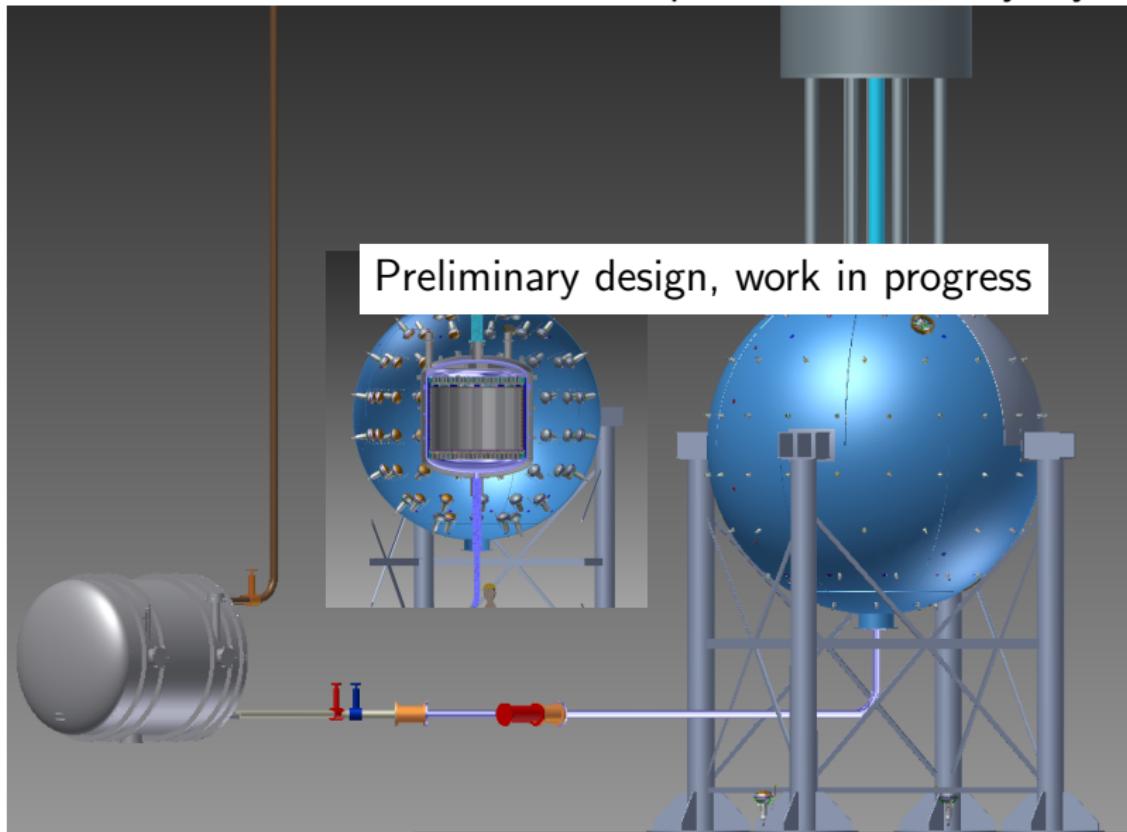
From	Via	To
CO <sub>2</sub> ,UAr,N <sub>2</sub> ,He	VPSA plant in CO $\lesssim$ 0.5kg/day	UAr,N <sub>2</sub> ,He
UAr, N <sub>2</sub> , He	Destillation@FNAL>10kg/day	UAr
UAr	Gettering at FNAL $\gtrsim$ 150kg/day	High purity UAr

**DarkSide-G2:** Collaboration with Air Products (He) and Kinder Morgan Doe Canyon CO<sub>2</sub> facility

From	Via	To
UAr, N <sub>2</sub>	Destillation in CO ~50kg/day	UAr
UAr	Gettering at FNAL $\gtrsim$ 150kg/day	High purity UAr

# The DarkSide-G2 recovery system

Fast transfer of ULAr from TPC to pre-cooled recovery cryostat.



# The DarkSide calibration system

"Articulated arm" source deployment system for DS-50 and DS-G2

Calibration of both LSV and TPC

Needs to accomodate DarkSide-G2 TPC

Flexible deployment system for various sources

Cameras for monitoring and source positioning



Conceptual design

—

—

—

—

—

—

—

—

—

—

—

—

—

—

—

—

Gaseous ER source deployment integrated in the gas system.

$^{83m}\text{Kr}$ ,  $^{39}\text{Ar}$ ,  $^{37}\text{Ar}$

